North Atlantic sub-decadal variability in climate models

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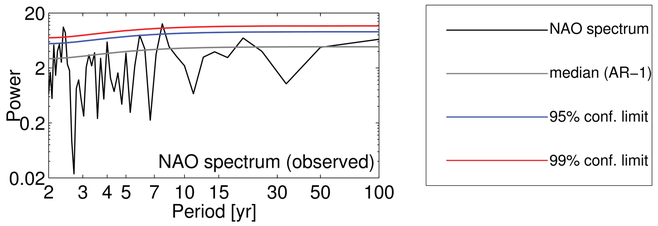
Introduction

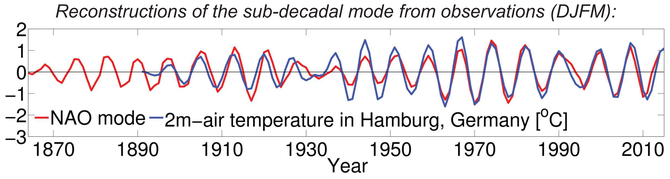
The North Atlantic Oscillation (NAO) is the dominant mode of winter climate variability in the North Atlantic sector (Hurrell et al. 2003). The NAO index describes the sea level pressure difference between the subtropical high and the subpolar low. This index exhibits variability on a wide range of timescales. In particular, the sub-decadal variability of the NAO is pronounced in observations and models (e.g., Deser and Blackmon 1993), but the underlying mechanism is still under discussion. Here we investigate the sub-decadal NAO mode using observations, model outputs from the Kiel Climate Model and from 12 CMIP5 models.

The power spectrum of the observed (based on HadSLP2 1850-2014) winter (DJFM) NAO index has a significant peak at 8 years:



The sub-decadal mode can also be also identified through Singular Spectrum Analysis (SSA) and explains 18% of the observed NAO index variability.

Reconstructions of the sub-decadal mode from observations (DJFM):



Kiel Climate Model (KCM - for details see Park et al. 2009)

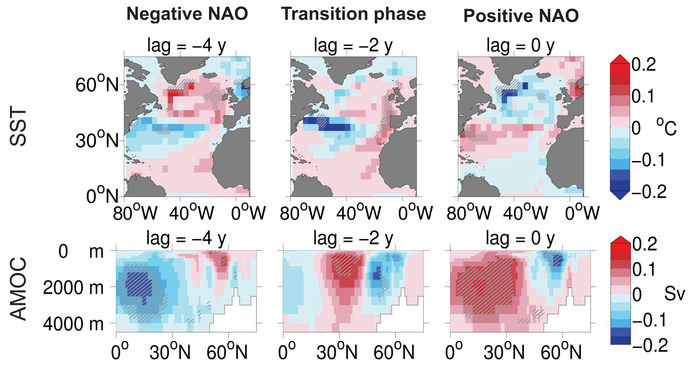
- atmosphere model: ECHAM5 [T31, L19]
- ocean sea-ice model: NEMO (OPA9-LIM2) [2° horiz., 31 vert. levels]
- analysis of 700 yrs from a present-day control simulation

CMIP5 models

- 12 models that provide min. 500 years
- unforced pre-industrial-control experiment

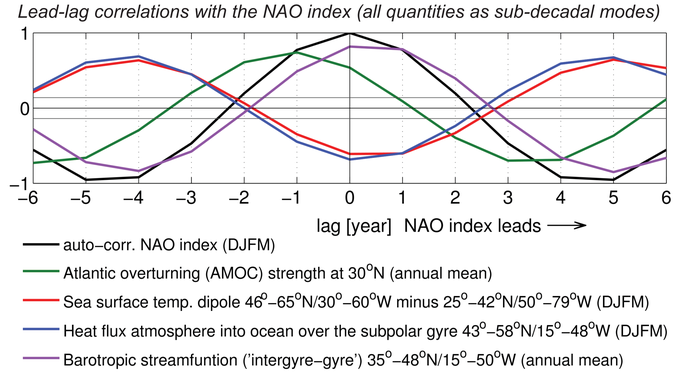
Mechanism in the Kiel Climate Model (KCM)

Also In the KCM the sub-decadal mode is the leading SSA mode of the NAO index. Lead-lag regressions on this mode suggest that the enhanced sub-decadal variability is generated through i) a positive feedback associated with a modulation of the barotropic streamfunction and ii) a delayed negative feedback associated with an adjustment of the Atlantic Meridional Overturning Circulation (AMOC): A dipolar anomaly in the AMOC during the transition phase reverses the anomalies of the sea surface temperature (SST) and finally causes a phase change of the NAO.



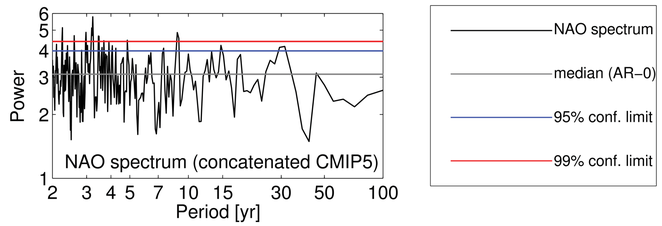
A sub-decadal SSA mode can be derived also from other quantities that describe the North Atlantic climate. Their modes are significantly lag-correlated with that of the NAO index. For their physical relations regarding the sub-decadal mode see Reintges et al. 2016.

Lead-lag correlations with the NAO index (all quantities as sub-decadal modes)



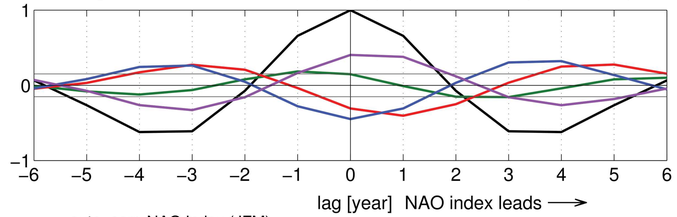
Confirmation from CMIP5 models

Also the 12 analyzed CMIP5 models exhibit pronounced sub-decadal variability in the North Atlantic. Though the exact periods differ, the power spectrum of the concatenated NAO timeseries (JFM) reveals significant sub-decadal peaks.



The CMIP5 model outputs were bandpass-filtered (5-15y) to capture the sub-decadal range. The multi-model mean lead-lag-correlations with the NAO index are shown in the figure below. A period of about 7 years – shorter than in the KCM - is pronounced and the correlations are weaker. Still, even the multi-model mean provides very similar relations between the shown variables.

Lead-lag correlations with the NAO index (all quantities bandpass-filtered)



Conclusions

Results from climate model simulations (KCM and CMIP5) and observations suggest: Air-sea interactions involving the NAO and the Atlantic Meridional Overturning Circulation (AMOC) are essential for the generation of the enhanced sub-decadal variability in the North Atlantic region.

The phase change within this mode is achieved through a delayed negative feedback of the AMOC on the NAO.

References

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Acknowledgements

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